

AN EXPERIMENTAL STUDY OF SUTURE OF ARTERIES WITH A DESCRIPTION OF A NEW SUTURE.¹

BY GEORGE MORRIS DORRANCE, M.D.,

OF PHILADELPHIA,

Assistant Instructor of Surgery in the University of Pennsylvania; Surgeon to the Out-patient Department of St. Agnes' Hospital.

THE methods of repair of arteries hitherto proposed are as follows:

I. MECHANICAL METHODS.—(a) Adhesive plaster methods, devised by Dr. G. E. Brewer. Advantage: The rapidity of application. Disadvantages: 1, A foreign substance is left in place; 2, secondary hæmorrhage occurs frequently; 3, obliteration of the vessel is common from too much pressure. (b) Abbe's method. The introduction of a glass tube in the lumen with suture of the artery. Advantage: Very slight chance of secondary hæmorrhage. Disadvantages: 1, The tube is a foreign body and by its presence causes irritation of the intima and produces thrombosis at the ends of the tube; 2, the tube may ulcerate its way out.

II. SUTURE METHODS.—(a) Invagination method devised by Dr. J. B. Murphy. Advantages: It gives a double thickness of the artery at the line of approximation. Disadvantages: 1, The artery is necessarily stretched; 2, the operative procedure difficult and long; 3, the lumen is narrowed; 4, the end of the artery allows fibrin ferment to enter the blood-stream; 5, fringes of intima hang in the blood current and assist in coagulation. (b) Suture of the outer two coats only. Advantages: None, over the through-and-through method. Disadvantages: 1, The blood can dissect its way between the

¹ Read before the Philadelphia Academy of Surgery, May 7, 1906.

coats of the artery and cause an aneurism; 2, fibrin ferment from the arterial walls has free access into the blood-stream; 3, fringes of intima hang in the blood-stream and assist in coagulation. (c) Through-and-through method. Advantage: Easy to perform. Disadvantages: 1, The suture is exposed to the blood-stream; 2, fringes of intima hang in the lumen. In the method now to be described attention is called to advantages: 1, The suture does not protrude in the lumen of the artery; 2, fibrin ferment cannot get from the ends or cut surfaces of the artery into the blood-stream; 3, the liability to secondary hæmorrhage is lessened by the double line of suture. Disadvantages: We have not observed any.

Description of the Suture.—Pagenstecher's thread Number One is used in the finest sewing-needle the thread will pass through. The clamps used are very limber-bladed forceps, devised by us especially for this work in order to avoid crushing the intima. The blades are covered with rubber tubing. (Figure 1.) Dissecting forceps are used to hold the edges of the artery. The suture can be used for a longitudinal, oblique or transverse (complete or incomplete) cut in the artery.

Method of Suturing a Longitudinal Cut.—(Fig. 2). The clamps are applied 2.5 cm. above and below the cut. The suture is started 1.5 mm. above the cut edge, the suture is passed through the outer two coats and tied, the end of the suture is grasped by a hæmostat, the needle is next passed through all the coats of the artery on both sides 1.5 mm. below the first suture and 1.5 mm. from the cut edge; the suture from now on is a continuous mattress with the dropping back one-half a suture length every third suture until the end of the incision is reached, then the suture is passed through the outer two coats 1.5 mm. below the lower end of the cut and a half-hitch made to tie the suture. The same suture is continued as a whip-stitch over the edges of the artery outside of the mattress suture until the starting-point is reached, when the two ends of the suture are tied. The artery is grasped in a gauze pad, the distal clamp removed, then the proximal clamp and the artery

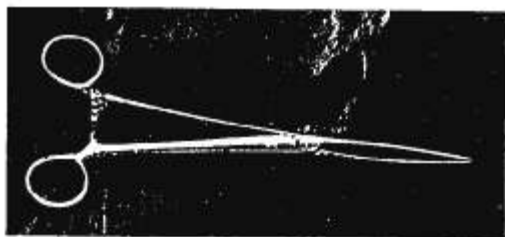


FIG. 1.—Special artery-clamp.

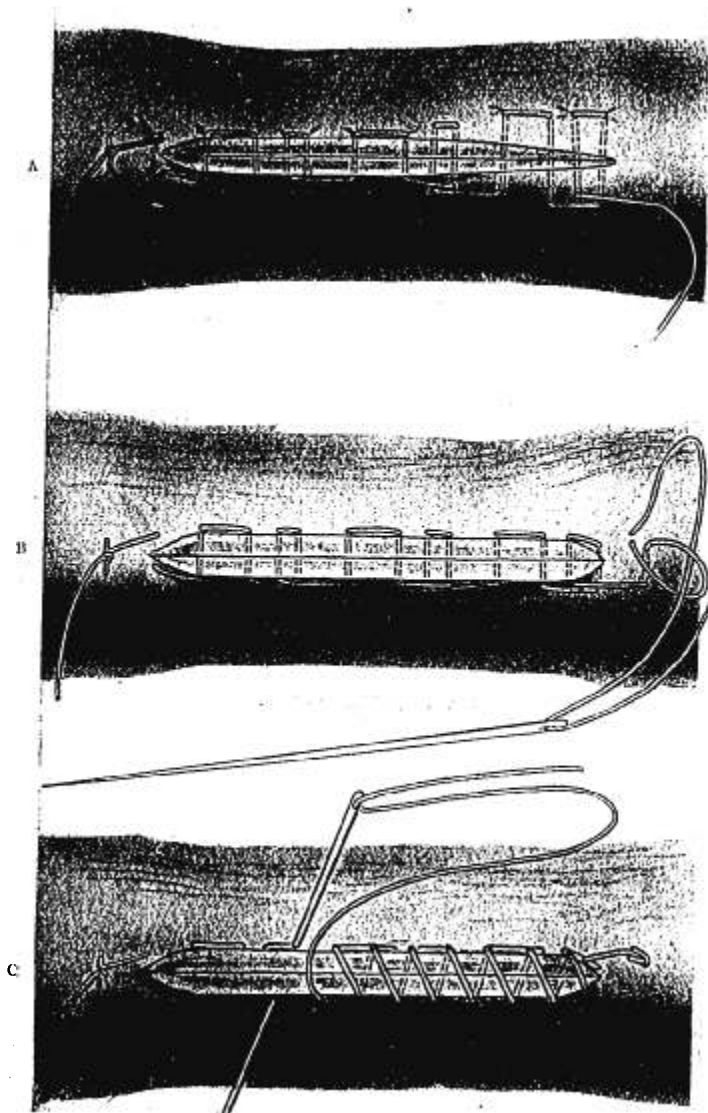


FIG. 2.—A, suture inserted and pulled tight in the lower half; B, suture inserted and pulled tight throughout; half-hitch made but not tightened; C, mattress suture pulled tight and half-hitch made, whipstitch partially inserted but not pulled tight.

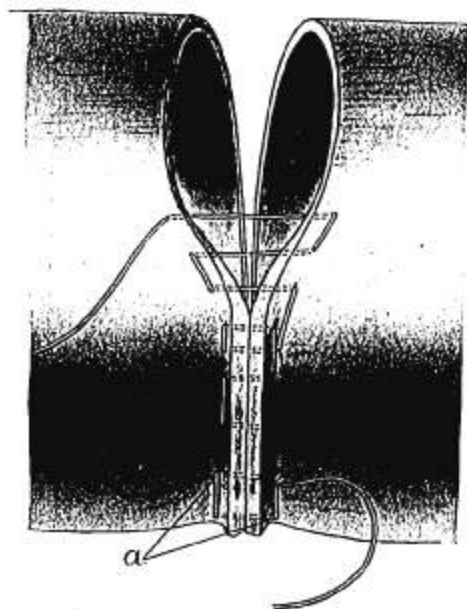


FIG. 4.—Suture of complete transverse wound ; A, mattress suture.

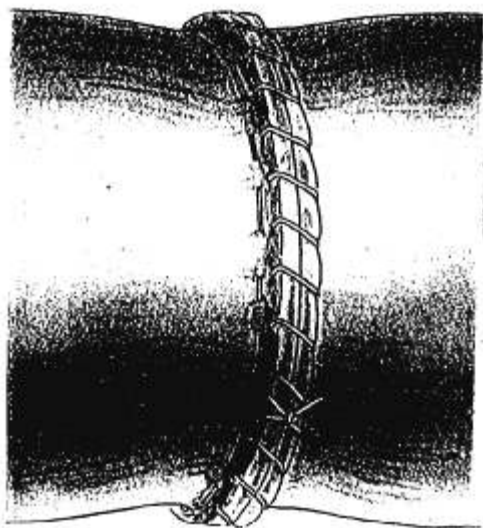


FIG. 5.—Suture of complete transverse wound, finished.

is dropped back in place and the deep fascia sutured around the line of approximation.

The method of suturing an oblique cut is practically the same as the longitudinal.

The Method of Suturing a Transverse Incision Half Way Through the Artery.—(Fig. 3.) The clamps are applied 2.5 cm. above and below the cut edges. The suture is started 1.5 mm. from the lateral end of the cut and passed through the outer two coats and tied; the end of the suture is grasped with a hæmostat. The suture is continued as a continuous-mattress suture, dropping back one-half a suture every third stitch until the opposite end of the cut is reached, then the suture is passed through the outer two coats and a half-stitch made to tie the suture; the same suture is continued back over the line of suture as an over-hand whip-stitch outside the mattress suture until the starting-point is reached, when the two ends are tied. The mattress suture should be 1.5 mm. from the cut edges at all times. The deep fascia should be sutured around the line of approximation.

The Method of Suturing a Complete Transverse Division of an Artery.—(Fig. 4, 5.) The clamps are applied as before. The cut edges of the artery are grasped with dissecting-forceps and the suture is passed through the upper edge of the artery from without in and through the lower end from within out; the needle is then reversed and brought back 1.5 mm. to one side of the former suture and tied. (This suture is really a single-mattress suture.) The suture is continued as a continuous-mattress suture, dropping back half a stitch every third suture until the starting-point is reached, then a half-stitch is made and the suture continued back as a whip-stitch until the starting-point is reached again; then the two ends are tied. The suture is started on the anterior surface near the handles of the clamps. When the suture reaches the farther side of the artery the handles of the clamps are taken from the lower portion of the wound and placed in the upper portion; in this way the surface of the artery which was anterior is now posterior, and the suture can always be kept in sight.

EXPERIMENTS.

CASE I.—Black horse, aged 20. Condition was very poor. The anæsthetic was chloral internally and chloroform by inhalation. An incision 20 cm. long was made on the left side of the neck, the carotid artery was found and the clamps were applied. A small vessel arising from the under surface of the artery was clamped and ligated. A longitudinal incision 4.5 cm. long was made in the artery. The artery was sutured, the clamps were removed and no hæmorrhage occurred. After the deep fascia was sutured around the line of approximation, the artery could be seen pulsating. The wound was sutured with through-and-through sutures of silkworm-gut. The horse died from the effects of the anæsthetic three hours after the operation. Through a mistake of the attendant, the specimen was not recovered.

CASE II.—Black horse, aged 20. Condition was very poor; there were several sloughing wounds and sinuses over the body. The anæsthetic was chloral and chloroform. An incision 22.5 cm. long was made on the right side of the neck; the carotid artery was found and the clamps were applied. The artery was divided transversely two-thirds the way through. The artery was sutured, the clamps were removed and no hæmorrhage occurred. After the deep fascia was sutured around the line of approximation, the artery could be seen pulsating. The superficial wound was closed with through-and-through sutures. The pulse was equal on both sides. Twenty-four hours after the operation the pulse was good and equal to that on the opposite side; the horse was unable to get up. Forty-six hours after the operation the pulse was equal on both sides; the horse was unable to get up and was killed by pithing. When the incision was opened up the wound was found to be infected; the artery was removed and examined; a very small lateral thrombus was present, but the lumen was not decreased. (Fig. 6.)

Pathological Report.—Gross specimen, preserved in a solution of formaldehyde, shows a portion of an artery dissected free from the periarterial tissues, the wall of practically normal thickness and without apparent gross trace of any marked hyperæmia. The vessel laid open shows the intima practically normal, save at site of the wound; the wound a partial transverse (slightly oblique) incision of the circumference, marked by a small clot extending in valvular fashion into the interior, and attached at the line of incision. This clot probably interfered but little, if any, with the flow of blood, and is apparently organized. The texture of the tissue of the wall shows no important gross changes.

Microscopic.—Section longitudinal, transverse to the line of operative wound. As seen in the section there extends from the line of closure of the incision a flap-like (valvular) thrombus into the lumen of the vessel, granular and fibrinous in structure, containing numerous scattered polynuclear leucocytes and a few eosinophilic cells. The wall of the artery is slightly thickened, its outer coat thickly infiltrated with poly-

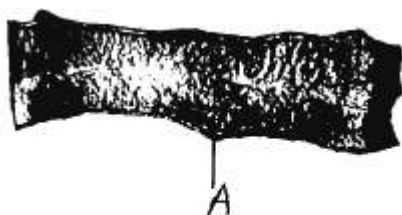
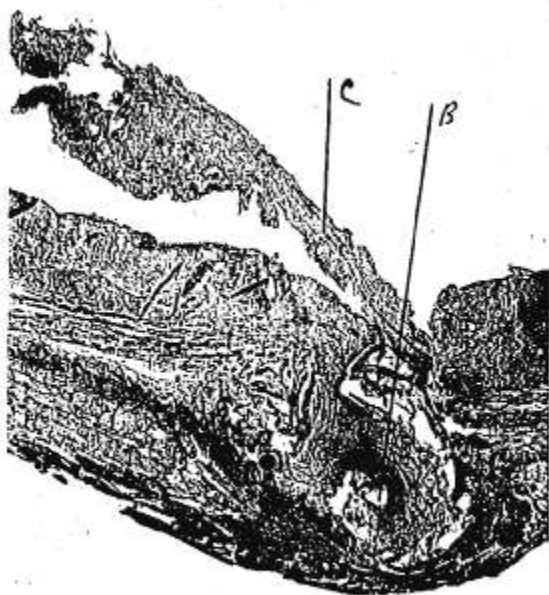


FIG. 6. CASE 2.—A, line of incision.



CASE 2.—B, remains of suture; C, small valvular thrombus.

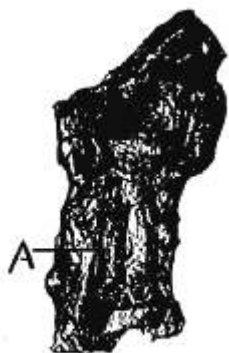
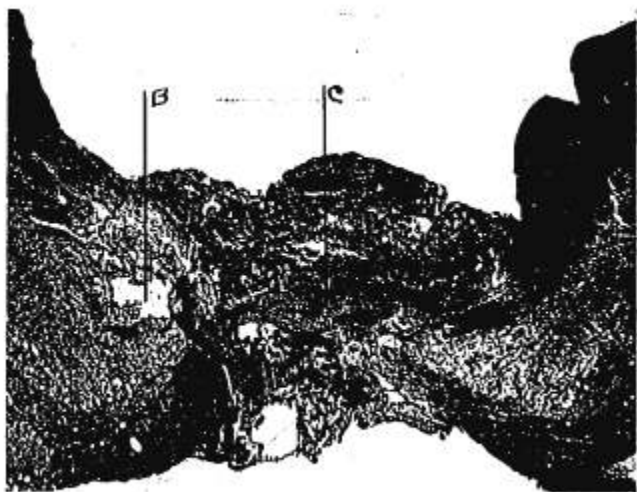


FIG. 7. CASE 3.—A, line of incision.



CASE 3.—B, remnant of suture; C, line of healing.

nuclear leucocytes, a smaller degree of the same type also existing in the other coats (prominent in part of the intima). The tissues in the line of enclosure (compressed by the sutures) are dense, more or less hyaline and staining without definition, and irregularly electing the hæmatoxylin and eosin tints. These tissues do not show any leucocytic infiltration. Especially in the outer coat the lymph-spaces are distended and contain a fibrinous coagulate, in which are seen scattered leucocytes. The endothelium of these spaces is swollen and occasionally desquamated. Throughout the wall but little cellular proliferation is evident.

CASE III.—Dog; Irish setter. Condition was good. The anæsthetic was morphine hypodermatically and ether by inhalation. The abdomen was opened and the abdominal aorta exposed 5 cm. above the common iliac artery; the clamps were applied and a longitudinal incision 2.5 cm. long was made in the artery. Bleeding occurred from the lumbar branches of the aorta, which were clamped and ligated. The artery was sutured with difficulty on account of the depth of the wound and the bleeding of the small veins. After the clamps were removed, the artery could be seen pulsating. Twenty-four hours after the operation the dog was in a weak condition, but the pulse was equal in both femoral arteries. Forty-eight hours after the operation the pulse could be felt in the femoral arteries, but was very rapid and weak; suppurative peritonitis was apparently present. Ninety-six hours after the operation the pulse could be felt in the femoral arteries; peritonitis was present, and as the dog was suffering acutely he was killed by chloroform. Post-mortem findings: Suppurative peritonitis was present; the artery was removed and opened up; a slight lateral thrombus caused by an infected suture was found. (Fig. 7.)

Pathological Report.—Gross specimen, a short length of abdominal aorta with its bifurcation, preserved in a solution of formaldehyde, shows the vascular wall with surrounding tissue closely adherent, and with discoloration from hyperæmia persisting. Laid open, the general intima shows no gross change. Over the line of longitudinal incision is a slight ridge of thrombosis apparently but little changed. The walls of the vessel, especially a little away from the line of closure (which is the thinnest part of the circumference), are thickened, hyperæmic and apparently the seat of inflammatory infiltration, but without gross appearance indicating suppuration.

Microscopic.—Section made transversely, at right angles with the line of operative wound. Over the incision in the lumen of the vessel lies a fibrinous thrombus, showing no organization as yet, with a rich polynuclear leucocytic infiltration along its base, and containing numerous hæmatoxylin-stained fragments (fragments of leucocytic nuclei). The line of incision shows a distinct mass of polynuclear leucocytes extending from the base of the clot to the exterior of the vessel. Tissue along the line of closure of the wound shows embedded suture, and it is densely hyaline in character, electing the eosin stain, being evidently necrotic. The general wall of the artery is deeply congested, at places infiltrated with blood; shows marked proliferation of the connective tissue, and

contains numerous polynuclear leucocytes, the latter densely infiltrating portions of the adventitia.

CASE IV.—Medium-sized dog. The anæsthetic was morphine and ether. The carotid artery was found on the right side of the neck, and the clamps were applied. A longitudinal incision 1.7 cm. long was made in the artery. The artery was sutured in the usual manner, the clamps were removed and no hæmorrhage occurred. The superficial fascia was sutured around the line of approximation, and the wound closed with through-and-through sutures. Twenty-four hours after the operation the dog was up and about, the pulsation was apparently normal. Three days after the operation the pulsation was normal, but the wound was infected. Four days after the operation the pulsation in the carotid artery was normal; the wound suppurating. The dog was killed on the fourth day; the artery was removed and opened up and a lateral thrombus was found.

Pathological Report.—The section of this specimen unfortunately takes in only one margin of the injury, which is apparently not closely approximated. The whole vessel wall is diffusely involved in acute inflammatory changes, with fusion of the similarly-involved surrounding tissue to the adventitia, so that no sharp demarcation of the outer coat of the vessel exists. Inside the vessel a comparatively fresh thrombus exists, adhering along the line of the wound. These tissues close to the line of injury are necrosed, taking diffusely and with poor definition the eosin stain; they are more or less diffusely infiltrated with blood, and the seat of numerous hæmic granules. Throughout the thickness of the vessel along this line the tissues are the seat of considerable leucocytic infiltration, of infection of the vasa vasorum, and of numerous round and spindle-shaped embryonic connective-tissue cells. Examples of phagocytic leucocytes are not infrequent.

CASE V.—Black horse, aged 20. Condition was very poor. An incision 22. cm. long was made on the right side of the neck; the carotid artery was found and the clamps were applied. The artery was cut completely across and end-to-end anastomosis was performed. Some difficulty was encountered in holding the edges together on account of having only one assistant and the horse shaking with a fine tremor. The clamps were removed and no hæmorrhage occurred. The deep fascia was sutured around the line of approximation. Twenty-four hours after the operation the horse was up and about, the pulse was good, full and equal on both sides. Three days after the operation the pulse was equal and the wound suppurating. Five days after the operation the pulse was good, full and equal on both sides; the wound was suppurating profusely. The horse was killed and the wound opened up; the artery was removed and incised; the lumen was not decreased, and no thrombus was present. (Fig 8.)

Pathological Report.—Gross specimen, preserved in a solution of formaldehyde, consists of a short segment of the artery freed from the surrounding tissues, with walls of apparently normal thickness and texture. Laid open, near the site of operation the intima is slightly



FIG. 8. CASE 5.—A, line of incision.



FIG. 9. CASE 6.—A. line of incision.



CASE 6.—B, remains of suture; C, line of healing.

nodular, apparently from slight focal swellings rather than from foci of thrombosis. The line of incision, a circular one, shows as a slight (circumferential) ridge a little less glistening than the adjacent intima, and presumably the seat of a small thrombus, which must, however, be partially organized. No distinct foci of softening from suppuration seen in gross inspection of the wall in section.

Microscopic.—Longitudinal section of artery (transverse to line of operative wound) shows a thin layer of granular clot over the site of wound; this clot is the seat of moderate leucocytic infiltration, especially toward the base (in clot numerous nuclear fragments probably from leucocytic disintegration). In one part of the clot evidence of beginning vascularization. On the outside of the vessel are several tiny foci of suppuration shown in the section, and in the inner muscular layer and intima is a similar infiltration somewhat more diffused. Little reparative activity evident, and the general wall remains thin, showing microscopically but little embryonic cell formation present in the layers. The tissue does not show a clear line of incision; an irregular fragmented part of the wall evidently represents the wound; and in this part there is a special tendency on the part of the tissues of the muscular coat to select the hæmatoxylin.

CASE VI.—Mouse-colored horse, aged 17. Condition was very poor. An incision 20. cm. long was made on the right side of the neck, the carotid artery was found and the clamps were applied. The artery was divided completely across and end-to-end anastomosis performed. The clamps were removed and no hæmorrhage occurred. The deep fascia was sutured around the line of approximation. The pulse was equal in both submaxillary arteries. Twenty-four hours after the operation the horse was up and about, the pulse was good, full and equal on both sides. Three days after the operation the pulse was equal on both sides and the wound suppurating. Five days after the operation the pulse was equal on both sides. Seven days after the operation the pulse was good, full and equal on both sides, and the wound was still suppurating profusely. The horse was then killed and the wound opened up; the artery was removed and incised; the lumen was not decreased and no thrombosis present. (Fig. 9.)

Pathological Report.—The gross specimen, preserved in a solution of formaldehyde, shows an artery with the surrounding tissues at the site of operation intimately adherent to the external part of the wall, and with traces of discoloration and hyperæmia. Laid open, the intima shows a circular, slightly depressed line of operative union, without clear evidence of thrombosis, but somewhat roughened as if from a small deposit of this type. The gross section of the wall presents just beneath the line of closure, which is apparently firm, a small focus of pale opaque appearance, its substance somewhat softer than the general tissue, and suggesting a point of suppuration about a suture. The tissue of the deeper part of the wall and the adjoining tissue have a succulent appearance suggesting inflammatory infiltration rather than dense fibrosis from complete healing.

Microscopic.—Section made longitudinally, transversely to line of

operation. There exists a small definite fibrous clot upon the intima just over the line of incision. The incision has been obliterated by partial healing, but the whole wall of the vessel is much thickened by an intense exudative inflammation. The outer wall is the seat of wide distension of its spaces which are filled by a fibrinous reticulum thickly beset with polynuclear and eosinophilic leucocytes, and at several points suppuration evidently is focalizing. The muscle-layers in both coats are separated and sharply outlined by a cellular infiltration particularly rich in eosinophilic cells, and the intima is much thickened, particularly by an embryonal cell infiltration, full of capillaries. Embedded in the tissue at the site of the wound is a suture about which is a marked suppurative infiltration, and in its vicinity there is more or less necrosis of the older tissue indicated by its hyaline appearance and strong election of the eosin stain. The suppuration only in a minor degree is invading the deeper part of the thickened intima, and is apparently a process implanted after healing had partially proceeded.

CASE VII.—Bay horse, aged 14. The diagnosis of thrombosis of the iliac arteries was made by Dr. John W. Adams. The horse was transferred to us through the kindness of Dr. Adams. The anæsthetic was chloral and chloroform. An incision 22. cm. long was made on the right side of the neck; the carotid artery was found and the clamps were applied. An oblique incision with ragged edges 2.5 cm. long was made in the artery. The artery was sutured, the clamps were removed and no hæmorrhage occurred. After the deep fascia was sutured around the line of approximation, the artery could be seen pulsating. The superficial wound was closed with through-and-through sutures. The pulse was equal on both sides. Twenty-four hours after the operation the pulse was good and equal on both sides; the horse was up and about. Three days after the operation the pulse was equal on both sides and the wound was suppurating. Five days after the operation the pulse was equal on both sides. Seven days after the operation the pulse was equal on both sides and the horse was in good condition. Nine days after the operation the pulse was good, full and equal on both sides; the wound was suppurating. The horse was killed and an autopsy was performed by Dr. C. Y. White. The thrombosis of the iliac arteries was found as diagnosed before operation. The incision in the neck was wide open and the artery could be felt in the bottom of the wound. The artery was removed, opened up and a slight lateral thrombus found, but the lumen was not decreased. (Fig. 10.)

Pathological Report.—Gross specimen, preserved in a solution of formaldehyde, consists of an artery with the surrounding tissue closely adhering to its outer part, and with traces of previous hyperæmia persisting. Laid open, a line of incision extending longitudinally is marked out by a thin, somewhat elevated and irregular thrombus, in places apparently partly organized, but at others still red and relatively unchanged. The general lumen of the vessel could not have been importantly impaired thereby. The intima in this part of the vessel is generally roughened, with nodules and slight ridges, which are apparently for the most part points of slight thrombus formation, and in part due to local thickenings

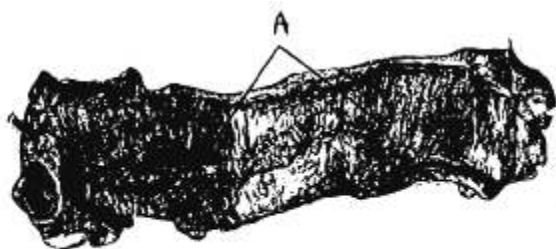
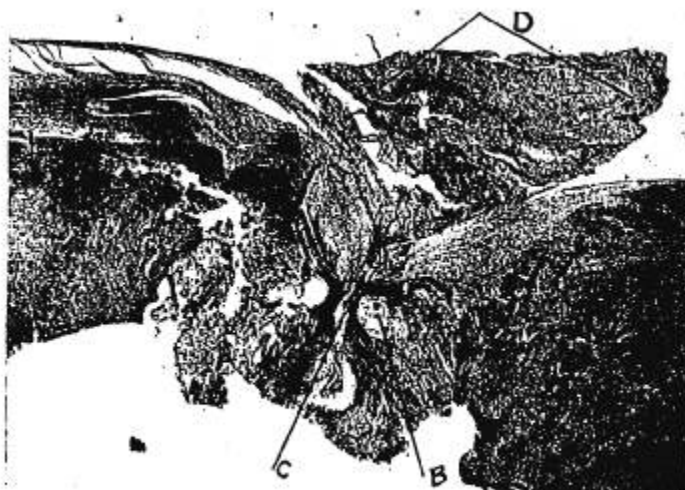


FIG. 10. CASE 7.—A, line of incision.



CASE 7.—B, remains of suture; C, line of healing; D, lateral thrombus.

of the intima. In cut section the thrombus is seen to be directly connected with the depression of linear closure of the arterial wound, and the intima generally seems redder than the deeper portions of the wall, the latter being, however, somewhat spongy and probably the seat of more or less inflammatory infiltration.

Microscopic.—Section made transversely to length of vessel, nearly transversely to the line of operative wound. Definite lateral thrombus overlying the line of wound shows no clear evidence of organization. Incision still to be traced through the whole thickness of the arterial wall; the tissues included within the sutures largely necrosed, hyaline, stained diffusely with the eosin of the hæmatoxylin and eosin preparation. From the borders of this hyaline part of the wall, marking the line of the wound adaptation, there extends diffusely through all the coats of the vessel a thick polynuclear leucocytic infiltration, in places (mainly media) rich in eosinophilic cells, with numerous endothelioid and embryonic connective-tissue cells interspersed. There is but little leucocytic infiltration in the clot, which, however, contains considerable hæmatoxylin-stained detritus, probably fragments of leucocytic nuclei.

CASE VIII.—Medium-sized dog. The anæsthetic was morphine hypodermatically and ether by inhalation. The carotid artery was found on the left side of the neck and the clamps were applied. An oblique incision 1.5 cm. long was made in the artery. The artery was sutured in the usual manner; the clamps were removed and no hæmorrhage occurred. The deep fascia was sutured around the line of approximation, and the wound closed with through-and-through sutures. Twenty-four hours after the operation the dog was up and about, and the artery was pulsating normally. Three days after the operation pulsation was apparently normal. His condition remained normal until he was killed, on the twelfth day. Post-mortem findings: The skin wound had united by first intention; the artery was removed and opened up; no thrombus was present, and the lumen was not decreased.

Pathological Report—Gross.—The artery is embedded in the surrounding tissues, which are closely adherent and are the seat of marked hyperæmia and inflammatory infiltration. Laid open, the vessel lumen is intact, the general intima smooth and glistening, and the line of incision marked by a small depressed linear scar.

Microscopically, there is marked hæmorrhagic infiltration in the surrounding tissues, together with numerous leucocytes and proliferated connective-tissue cells. No foci of suppuration. The whole wall of the vessel is the seat of numerous embryonic connective-tissue cells, mainly as fibroblasts. The line of incision is obliterated by a young scar. No appearance of thrombosis overlies this upon the intima, which is somewhat thickened and puckered at the site of the wound, but otherwise practically normal.

CASE IX.—Mongrel dog. The anæsthetic was morphine and ether. The carotid artery was found on the left side of the neck, and the clamps were applied. A longitudinal incision 1.5 cm. long was made in the artery. The artery was sutured in the usual manner; the clamps were

removed and no hæmorrhage occurred. The deep fascia was sutured around the line of approximation, and the wound closed with through-and-through sutures. Twenty-four hours after the operation the dog was up and about, the pulse being apparently normal. Three days after the operation the pulsation was normal, but the wound was infected. The animal was normal until he was killed, on the fourteenth day. Post-mortem report: The artery was immediately removed and opened up; a small lateral thrombus was present.

Pathological Report.—The artery contains a thrombus composed mainly of red cells and a granular fibrin, with at one place numerous polynuclear leucocytes penetrating the mass. No evidence of actual organization of thrombus; and no appearance, in sections examined, of endothelial or subendothelial proliferation in reaction to thrombus; the only changes of this type are along the line of wound of the artery-wall. In the latter line of incision, which is quite approximated and closed, the wall of the artery from without to the endothelial lining is the seat of a mass of well-formed fibroblasts, uniting the approximated surfaces; and close to the cut and over it the endothelium shows as a single (at few places double) line of pyriform cells projecting into the lumen of the vessel, but apparently quite free from the clot within. At one point, close to the cut in the adventitia, and upon the opposite side of the artery in the surrounding fat tissue, are minute foci of suppuration. Remnants of the sutures persist. Apparently in this case the healing of the wound and the thrombus are not synchronous processes; the latter is too fresh to date back to the origin of healing. Perhaps it is a thrombus occurring secondarily in connection with the suppuration which is evidently beginning in the arterial coat. The healing itself seems, even to the formation of an endothelial lining, to be progressing favorably.

CASE X.—Bay horse, aged 18. His condition was very poor. The anæsthetic was chloral and chloroform. An incision 22. cm. long was made on the right side of the neck; the carotid artery was found and the clamps were applied. One of the usual clamps was lost, and in its place a heavy hysterectomy forcep was used on the proximal end of the artery. The artery was divided completely across and circular end-to-end anastomosis performed. The clamps were removed and no hæmorrhage occurred. After the deep fascia was sutured around the line of approximation the artery could be seen pulsating. The wound was closed with through-and-through sutures. The pulse was equal on both sides. Twenty-four hours after the operation the horse was in good condition and the pulse equal on both sides. Three days after the operation the pulse was not as full or as strong on the operative side. The wound was suppurating. Four days after the operation the pulse was decidedly less on the operative side. Five days after the operation the pulse was very small on the operative side and the wound was still suppurating profusely. From the fifth to the fourteenth day the pulse gradually increased in volume and strength, but was not equal to the normal side at any time. The horse was killed on the fourteenth day by bleeding from the opposite side. The artery was removed and opened; a thrombus that almost filled

the artery was found, extending from the position of the heavy clamp down to the line of suture. Through a mistake of the attendant the horse was injected with formalin before the artery was removed. The thrombus was not of recent origin, so could not have been caused by the formalin.

Pathological Report.—The specimen examined grossly after preservation in a solution of formaldehyde shows an artery embedded in the surrounding tissues, and poorly defined from those about the level of operation. There is no evidence in the preserved specimen of any intense hyperæmia or hæmorrhagic infiltration of the tissues. Laid open, the vessel shows a dark, obstructing clot, which was slightly adherent along the line of operation, and which shows a more or less lamination on cross section. The line of incision is a circular one; it is somewhat puckered and overlaid by remnants of the clot, where the latter is torn off in the examination, and is superficially apparently firmly united. In section of the wall immediately beneath the slightly thickened intima at the site of closure are several points of softening apparently from suppuration and seemingly about the sutures. The general tissue at this site is soft and spongy, suggesting decided inflammatory infiltration.

Microscopic.—Section at site of operative lesion shows a thin, parietal granular (plaque) thrombus almost limited to the line of incision. The intima is thicker than normal near the lesion, but densely fibrous. Its endothelial coat is lost near the incision, and here its tissue stains with poor differentiation and strongly with the eosin of the hæmatoxylin-and-eosin preparation, giving the appearance of necrosis. Embedded beneath the intima is a loop of the suture used. This suture is surrounded by a dense infiltration of polynuclear leucocytes, and extending from this focus to the subendothelial portion of the intima on each side of the incision may be traced an infiltrating line of the same elements, along the border of the above necrosed part of the intima. The whole coat of the vessel is thickened, but definite suppuration is confined to the vicinity of the suture. The deeper coats are richly studded with round and spindle-shaped embryonic connective-tissue cells, with scattered leucocytes (numerous eosinophiles), and in the spaces of the adventitia the endothelium is swollen and often proliferated.

CASE XI.—Medium-sized dog. The anæsthetic was morphine hypodermatically and ether by inhalation. The carotid artery was found on the left side of the neck, and the clamps were applied. A longitudinal incision 1.5 cm. long was made in the artery. The artery was sutured in the usual manner; the clamps were removed and no hæmorrhage occurred. The deep fascia was sutured around the line of approximation and the wound closed with through-and-through sutures. Twenty-four hours after the operation the dog was up and about; the pulsation in the carotid artery was apparently normal. The animal remained normal until he was killed, on the twenty-first day after the operation. The artery was removed and opened up, no thrombus or narrowing of the lumen being present. (Fig. 11.)

Pathological Report.—Transverse section at site of injury shows complete healing of the intima, with perfect endothelial line. Intima at this

point thickened, the thickening impinging upon the deeper tissues rather than protruding into the vascular lumen. Inner elastic lamina perfect beneath the subendothelial thickening. The thickened intima is for the most part fully fibrous, but strands of embryonic cells (fibroblasts) pass

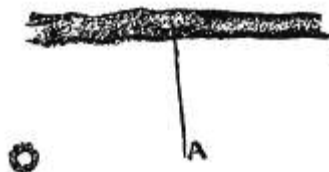
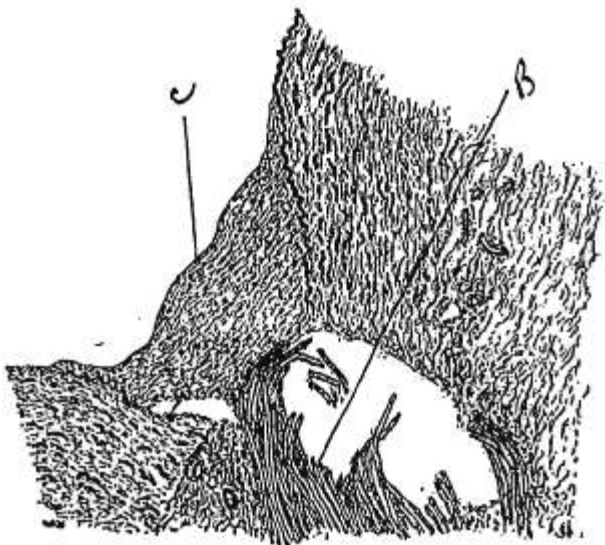


FIG. 12. CASE II.—A, line of incision.

into the mass along with capillary vessels. No evidence of thrombus on the intima. In the media there persist strands of the sutures with considerable young connective tissue intervening among the muscle-bundles.



CASE II.—B, remains of suture ; C, line of wound completely healed.

Here the elastic layers are somewhat broken in their continuity, but are quite apparent and show no appreciable degenerative changes. About the sutures among the young connective-tissue cells a few foreign-body giant-



FIG. 12. CASE 12.—A, line of incision.



CASE 12.—B, remains of suture; C, line of healing.

cells are present. The adventitia presents practically the same features as just described in the media, and is slightly thickened from the fibrosis and young connective-tissue elements.

CASE XII.—Mouse-colored polo pony, aged 17. His condition was very poor. The anæsthetic was chloral and chloroform. An incision 22. cm. long was made on the right side of the neck; the carotid artery was exposed and the clamps were applied. A longitudinal incision 3.5 cm. long was made in the artery. The artery was sutured, the clamps were removed and no hæmorrhage occurred. The deep fascia was sutured around the line of approximation, and the superficial wound closed with through-and-through sutures. The pulse was equal on both sides. Twenty-four hours after the operation the horse was up and about, the pulse was equal on both sides. Three days after the operation the pulse was equal on both sides and the wound was suppurating. The pulse was equal on both sides until he was killed, on the twenty-first day. Post-mortem findings: The artery could be felt at the bottom of the wound. The artery was removed and opened up; the lumen was slightly decreased, but no thrombus was present. (Fig. 12.)

Pathological Report.—The gross specimen, preserved in a solution of formaldehyde, consists of an artery closely welded with the surrounding tissue, traces of well-marked hyperæmia being present in the latter in the neighborhood of the operative wound. Laid open, the lumen is seen to have been permeable; the intima is marked by a slightly-elevated longitudinal line of about 3.5 cm. in length, thus presenting the appearance of recent scar-tissue rather than of an unorganized clot. Its irregular outline suggests, however, that it represents an organized linear thrombus rather than a direct adhesion of the applied surfaces of the intima. Transverse section inspected grossly corresponds with the above idea, the linear scar above mentioned being distinctly elevated above the surrounding surface of the intima, and below it in the wall are seen tiny foci of a softer, opaque substance suggesting points of suppuration; the deeper parts of the vessel-wall and the immediately-surrounding structures have a somewhat spongy or succulent appearance, suggesting marked inflammatory infiltration.

Microscopic.—Transverse section of artery, at right angles to the line of operative incision, shows over the site of operative line a small partly-organized thrombus. The organization is more perfect along the lateral borders of the clot. At its base, close to the line of the incision, there begins a polynuclear infiltration which continues outward through the intima to become especially marked about an embedded suture. The tissue between two strands of this suture (evidently section of the loop) is necrotic, almost hyaline, and poorly staining. All the coats are thickened and studded with embryonic elements, scattered leucocytes (many eosinophiles especially near the line of suppuration), and endothelioid cells (proliferated endothelium of lymph spaces). In several foci presumably near a suture giant cells are found in greater or smaller numbers. The general appearance here suggests that the clot was of earlier occurrence than the suppuration, and that the latter process is penetrating into the partly-healed wound.

CASE XIII.—White horse, aged 20. The anæsthetic was chloral and chloroform. An incision 22. cm. long was made on the right side of the neck; the carotid artery was exposed and the clamps were applied. A longitudinal incision 3.7 cm. long was made in the artery. The artery was sutured, the clamps were removed and no hæmorrhage occurred. The deep fascia was sutured around the line of approximation and the superficial wound closed with through-and-through sutures. The pulse was equal on both sides. Twenty-four hours after the operation the horse was up and in good condition, the pulse being equal on both sides. Three days after the operation the pulse was equal on both sides; the wound was suppurating. The pulse was equal on both sides until the horse died, from a small secondary hæmorrhage, on the thirty-third day. The artery was removed from the wound and examined. It opened into a pus sac which completely surrounded the artery; the lumen was not decreased, and no thrombus was present. It did not seem possible the horse could have died from the small secondary hæmorrhage, but no other cause could be found. (Fig. 13.)

Pathological Report.—The artery contains a thrombus composed mainly of red cells and a granular fibrin, with at one place numerous polynuclear leucocytes penetrating the mass. No evidence of actual organization of thrombus; and no appearance in sections examined of endothelial or subendothelial proliferation in reaction to the thrombus; the only changes of this type are along the line of wound of the arterial wall. In the latter line of incision, which is quite approximated and closed, the wall of the artery from without to the endothelial lining is the seat of a mass of well-formed fibroblasts uniting the approximated surfaces, and close to the cut and over it the endothelium shows as a single line of pyriform cells projecting into the lumen of the vessel, but apparently quite free from the clot within. At one point, close to the cut in the adventitia and upon the opposite side of the artery in the surrounding fat-tissue, are minute foci of suppuration. Remnants of the sutures persist. Apparently in this case the thrombus is too fresh to date back to the origin of healing. Perhaps it is a thrombus occurring secondarily in connection with the suppuration which is evidently beginning in the arterial coat. The healing itself seems, even to the formation of an endothelial lining, to be progressing favorably.

CASE XIV.—Sorrel horse, aged 18. The anæsthetic was chloral and chloroform. An incision 22. cm. long was made in the right side of the neck; the carotid artery was exposed and the clamps were applied. The artery was divided transversely two-thirds the way through and then sutured, the clamps were removed and no hæmorrhage occurred. Some difficulty was encountered in suturing because of a very fine tremor. The deep fascia was sutured around the line of approximation, and the superficial wound closed with through-and-through sutures. The pulse was equal on both sides and the horse was in good condition. Twenty-four hours after the operation the pulse was equal on both sides. Three days after the operation the pulse was equal on both sides and the wound was infected. The pulse were equal until the tenth day, when the pulse on the

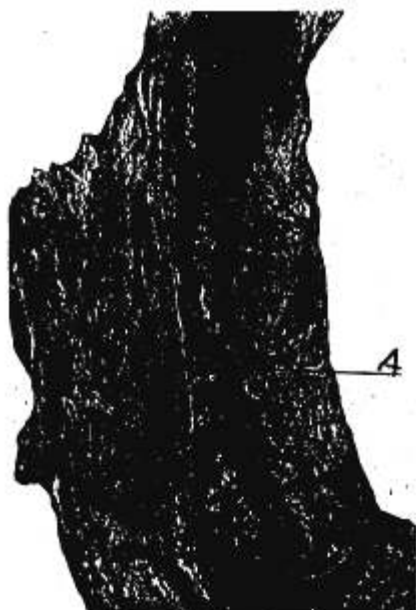
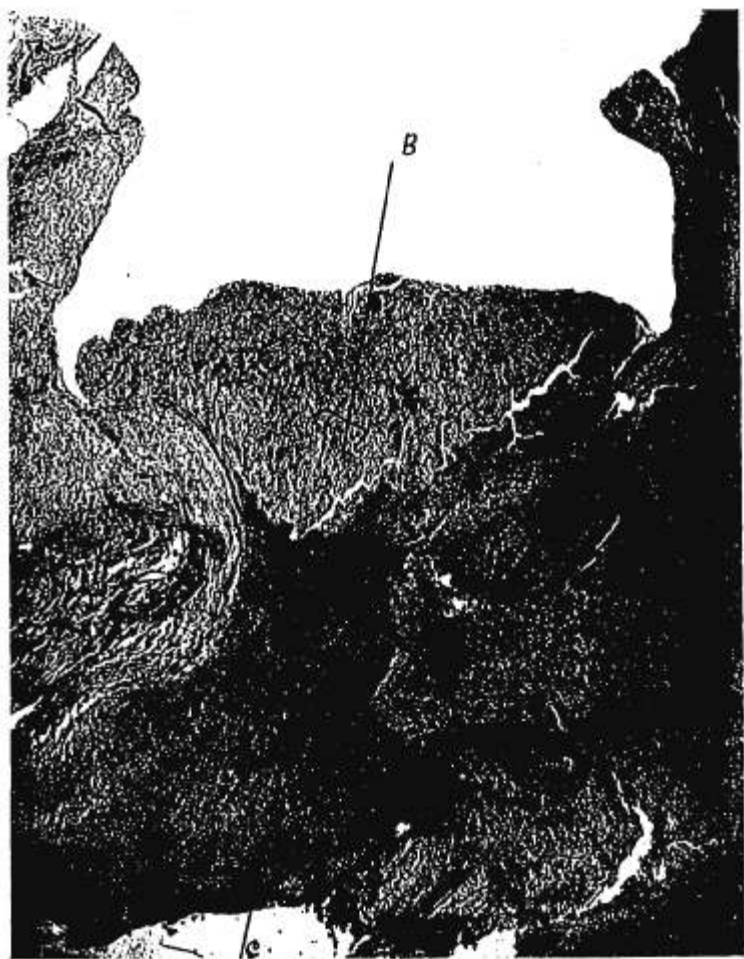


FIG. 13. CARR 13.--A, line of incision.



CASE 13.—B, lateral thrombus; C, pus.

operative side was slightly less. The wound was suppurating profusely. From the tenth until the eighteenth day the pulse was decidedly less on the operative side. From the eighteenth day until the forty-second day the pulse gradually increased in volume, but was not equal to the opposite artery at any time. The horse was killed on the forty-second day. The wound was suppurating profusely. The artery was removed and opened up. Complete thrombosis was found. In dissecting out the artery the vein was found very much thickened.

Pathological Report. Gross Specimen.—Two lengths of the vessel, preserved in a solution of formaldehyde, are presented for examination; both are the seat of occluding thrombosis; the thrombi are dark in the central part and paler and more or less organized and adherent to the intima along the periphery. The general wall of the artery is thickened, pale and dense from sclerosis. No appearance of suppurative softening on gross inspection.

Microscopic.—A section made transversely to the length of the vessel contains a large thrombus with organization proceeding, the greater part of the clot being well cellularized. Phagocytic leucocytes are numerous in the interior of the clot. No evidence of suppuration present. Distinct extension of fibroblasts and young vessels from the intima. The general coat of the vessel shows no evidence of suppuration; the blood-vessels are slightly injected, their coats are unusually thick; but little embryonic cell-formation is evident; when seen it mainly exists about the vasa vasorum, in the adventitia, and between the muscle-bundles of the media.

There were fourteen operations in all—nine on horses and five on dogs. The experiments on the nine horses and one dog were performed at the Veterinary Hospital of the University of Pennsylvania. The operations on the remaining four dogs were performed in the surgical operating-room of the medical laboratory. All the cases operated on at the Veterinary Hospital suppurated, and half of those at the laboratory. The operations on the horses were three complete circular, two transverse, three longitudinal and one oblique; on the dogs, four longitudinal and one oblique. When the arteries were opened up, in seven no thrombus was visible, in five a slight lateral thrombus was present; in one case we used a heavy hysterectomy forcep instead of our special clamp (clamp lost in transporting instruments), and almost complete thrombosis was present from the position of the clamp to the line of suture; in another case complete thrombosis occurred from infection around the artery. One ruptured on the thirty-third

day into a pus-sac surrounding the artery, but no thrombus was present.

Conclusions.—1. Only one secondary hæmorrhage occurred, and that one was directly traceable by microscopical examination to infection from without; this alone is a distinct advantage over the older methods. 2, Under the aseptic conditions employed in human surgery the results ought to be perfect, as our thrombosis can almost always be traced to infection. 3, Whatever suture used, the principle of placing the intima to intima is absolutely essential. 4. The suture must be kept out of the blood-stream.

In closing I wish to acknowledge my indebtedness to Dr. De Forest Willard for his many valuable suggestions and for the financial aid which made it possible to perform these experiments, and to Dr Allen J. Smith for the pathological reports. I also wish to thank the staff of the Veterinary Hospital for their many courtesies and Dr. Barnett, Resident Physician, in particular, for valuable assistance in many ways and for untiring efforts in my behalf; Mr. H. S. Hutchinson and Mr. F. Beekman, of the third-year medical class, for their assistance.